Process Control- Design, Analysis and Assessment
Doctoral Research Scholar Manikandan S
Department of Chemistry
Indian Institutes of Technology, Madras
MATLAB Tutorial – Controller Design – Part 1

Welcome everyone to the Matlab tutorial for process control analysis, design and assessment. Today we are going to look at the design of two controllers which are applied on seesaw control but they have more than one controller in place, they are cascade control and feed forward control. Let us look at each of them individually.

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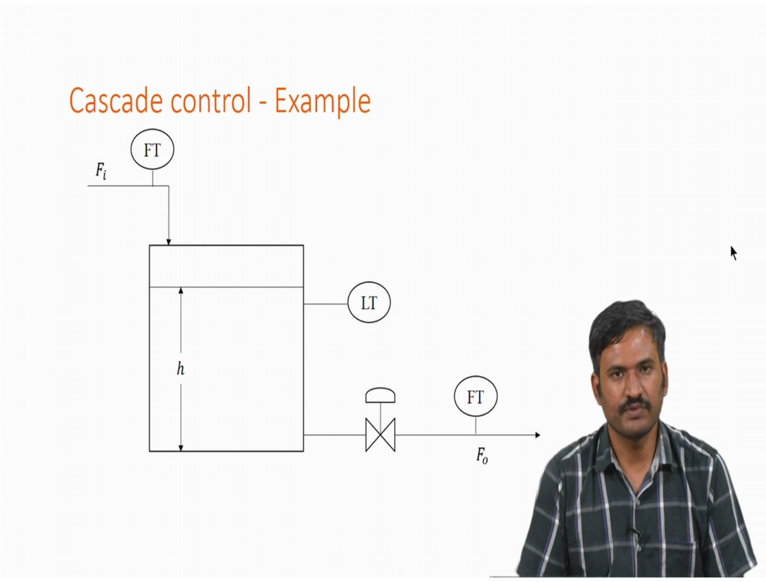

The cascade control where it is used is the question we 1st have to answer, let us take an example of this simple tank system where there is an inlet flow and then outlet flow. Outlet flow is through a control valve is present here and the level of the tank is also measured. Now given the system, what are the possibilities of controlling the system so that the level does not either increase or dry out. Now one simple way of controlling is just to use the outlet flow rate measurement and use that along with a flow set point to control the valve position here. Now this is how most of the traditional controllers will be done or we can do in another way where the level to twitter can directly control this valve using a set point tool level measurement.

Now if the tank is large and it has higher volume capacity then any change in level will be very small with respect to the inlet flow change so we will not we will not observe any change in the level as quick as the inlet flow rate changes, so we will take long time for the level to change and that will drive this controller valve to increase the flow rate, because of that we will have oscillatory level measurement. Suppose let us take this case where the output flow rate is directly used to control this level, then there is no information for this flow controller from this level.

So this flow controller only looks at the set point of the outlet flow which we are setting and the flow transmitter reading and with this error it controls the control valve opening so there is no information about either the variation of FI or the variation of level which is indicated by the level transmitter LT. Now this cascade controller looks at controlling introducing another controller in addition to this flow control valve, let us see how it can be done.

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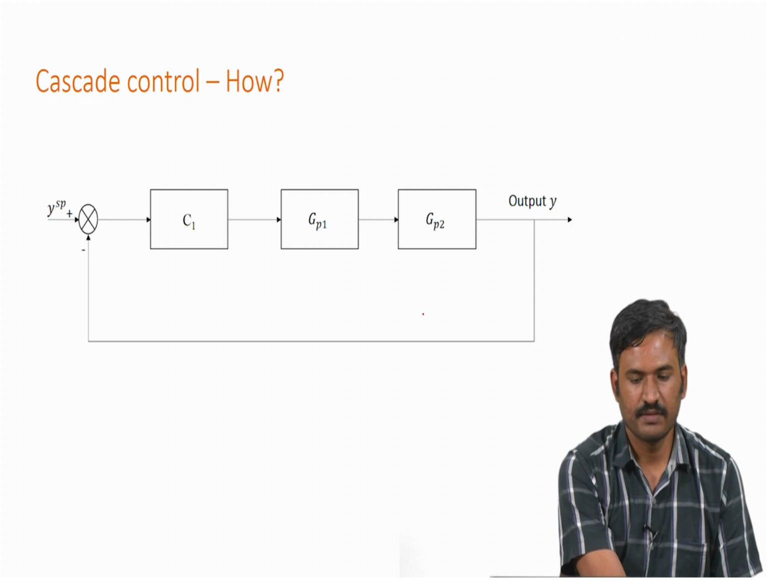

Suppose we can decompose the process into 2 different processes and we can measure the intermediate variable then this is how it will look without any cascade control, so the problem is if this GP 1 has higher time constant R, if it has sufficient amount of delay then any effect of this controller will be felt only after this time delay or this precedent time in the output. So irrespective of the tuning of this controller we may not be able to control the output such that it reaches the set point quickly. So in this case if there is a measurement available in between GP 1 and GP 2 then we can think of adding another layer of controller which is cascaded along with this original controller.

Now in this configuration notice that we have added one more controller C 2, and this controller controls the process 1, this loop is called inner loop or slave loop of the cascade control, the outer loop are the master loop is consist of everything including the inner loop.

Now notice that the set point of the 2nd controller is set by the controller C 1, so any change in the output as measured by the measurement device will change the setpoint of the controller to by controller 1, and this controller two will act as fast as possible because of the fact that we are measuring the output of GP 1 here.

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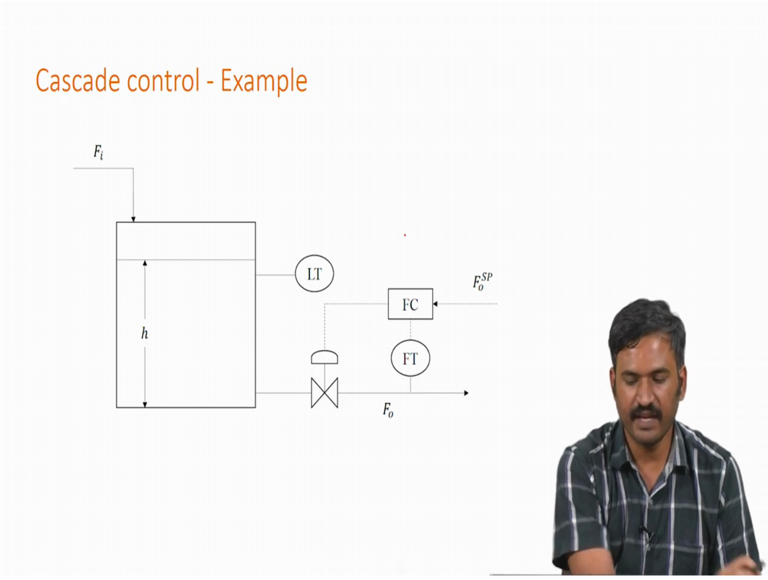

Now the 1st case where only the flow transmitter of the tank system is used to control the flow controller looks like this. So the flow transmitter gives the measurement to flow controller flow controller here, and with respect to flow set point this flow controller will manipulate the control valve given here. And we have the measurement of this level also we can have another controller in cascade with this flow controller such that the level measurement gives its measurement to a level controller which compares it with a set point and give the output to the set point of the flow controller. Notice that the flow controller set point which was manual before has become automatically changed in the cascade configuration. Now let us look at performance of a system in both without cascade controller and with cascade controller and see how the performance looks like.

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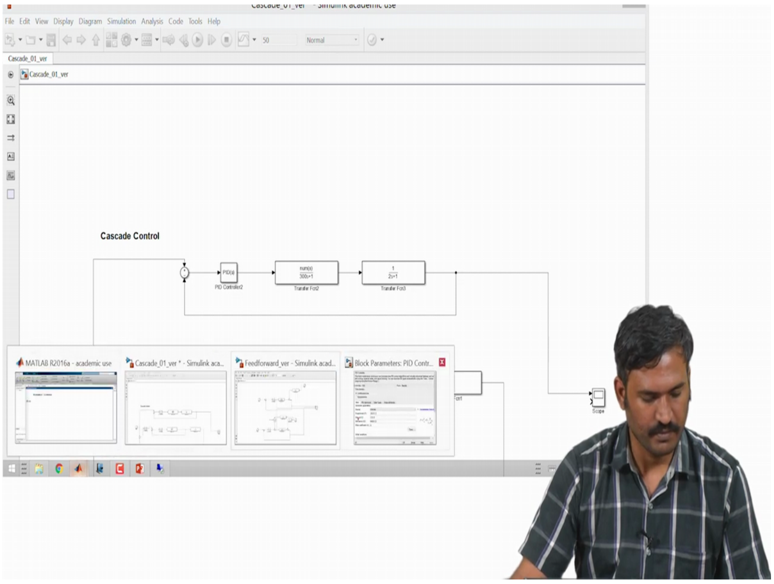

So you have configured two different systems, as you can see there is a step change in the set point of the controller and we have one PID controller over here, and this constitutes GP 1 and GP 2. Notice that denominator coefficient of GP 2 is that is denominator of GP 2 are the time constant of GP 2 is 300 seconds which is like 5 minutes, and the 2nd process which is in series has 2 seconds time constant. Now as you can see that a sufficiently high difference between these 2 individual transfer function, because of that let us see how the performance looks without cascade configuration and see how it improves once have cascade configuration, let us run the code and see how the trend looks like.

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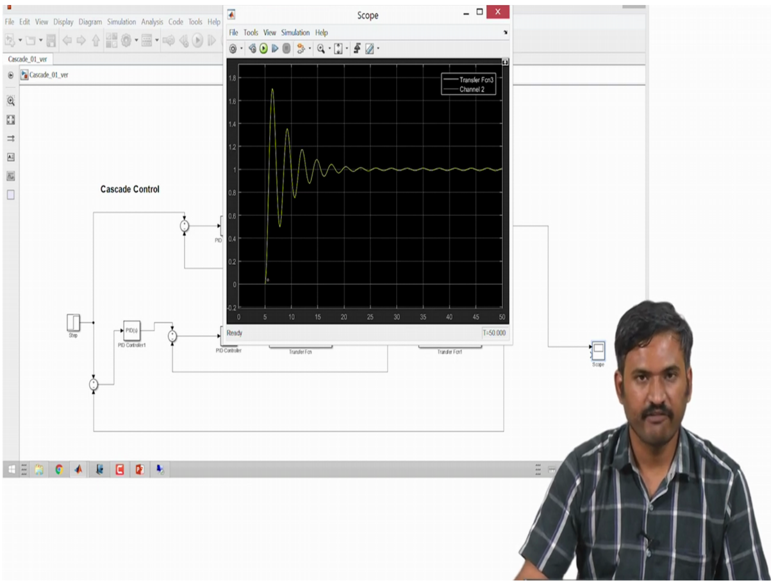

Now I have given the step response at 5 seconds, step change at set point is 5 seconds, as you can see there is sufficiently high oscillations for like 25 seconds, then it settles down into fairly stable response. Now the PID controller is tuned such that we have closed loop transfer function of 1 by 1 1 S + 1.

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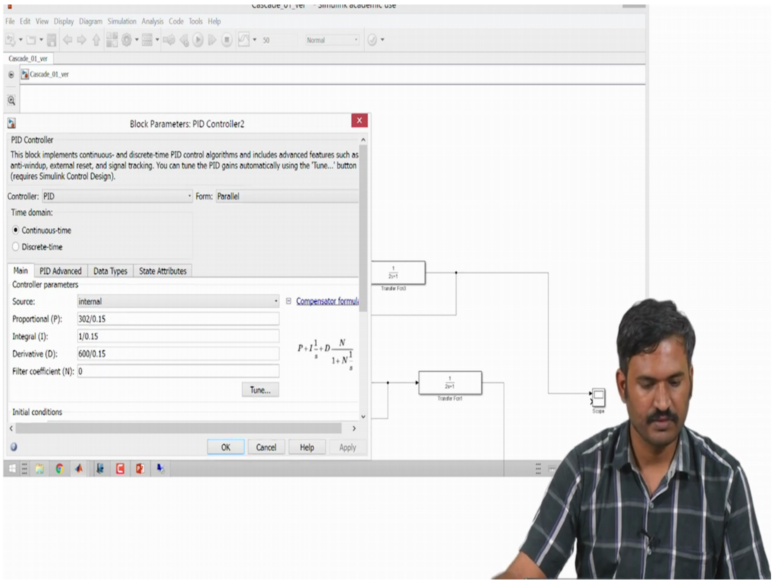

So that you can see here, and the same controller has been configured here along with cascade configuration, now let us see how this looks and compare both the configuration without cascade control and the configuration with cascade control. So now as you can see, the response of the transfer function with cascade control is fairly stable, there are no oscillations which is present in the configuration without cascade control so the main idea behind this simulation is that the cascade control is required when we have additional information present in the system and the system can be decomposed into more than one transfer function. In such cases we can we can include additional controller, and this controller changes the process transfer functions such that the whole complete closed loop can be controlled in a better way.

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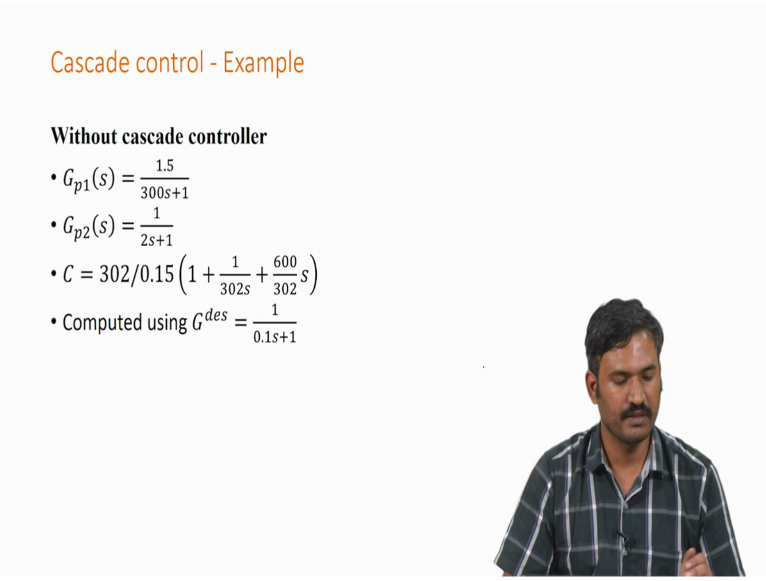

Now the tuning parameter and how the values have been arrived at are given in this slide. So without cascade controller the process transfer function is 1.5 S divided by 300 S + 1 and the controller configuration is given here. The same way with cascade controller the main difference between this cascade controller and without cascade control is that the 2nd controller C 2 controls only the 1st process GP 1 so the controller has been designed based on GP 1 alone, not including GP 2. Then C 1 is tuned by trial and error, you can as well tune using (())(12:01) method or similar methods. Those require capitation of open loop transfer function so that will include GP 1 C 2 divided by 1 + GP 1 C 2 times GP 2 as the open loop transfer function and then we have to compute the controller configuration using direct synthesis method.

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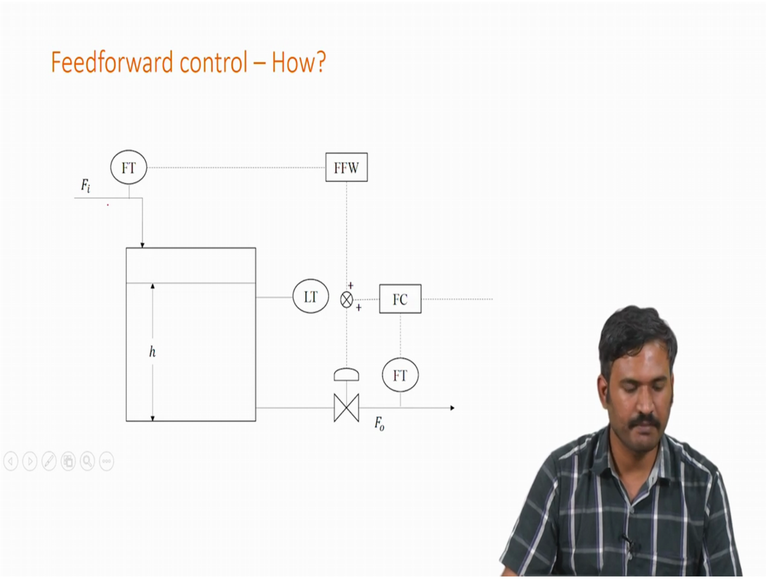

With respect to feed forward control where we can use and when there is a need for such control is a question we will answer with this example where we have the same example of large tank having one inlet flow and one outlet flow. Suppose the inlet flow is measured and the inlet flow has much variations then the level of the tank will keep on varying because of that you will have variations in this outlet flow also. If you have cascade controlling such scenario then you may end up having oscillations in both level and flow, but may not be desirable.

So in that case we can take this information of inlet flow rate directly to our controller which is feed forward controller and use that allow the traditional flow controller which we have here so that the flow transmitter measures the outlet flow compares with flow set point and gives the output to control the valve, so we add along with the flow controller present here.

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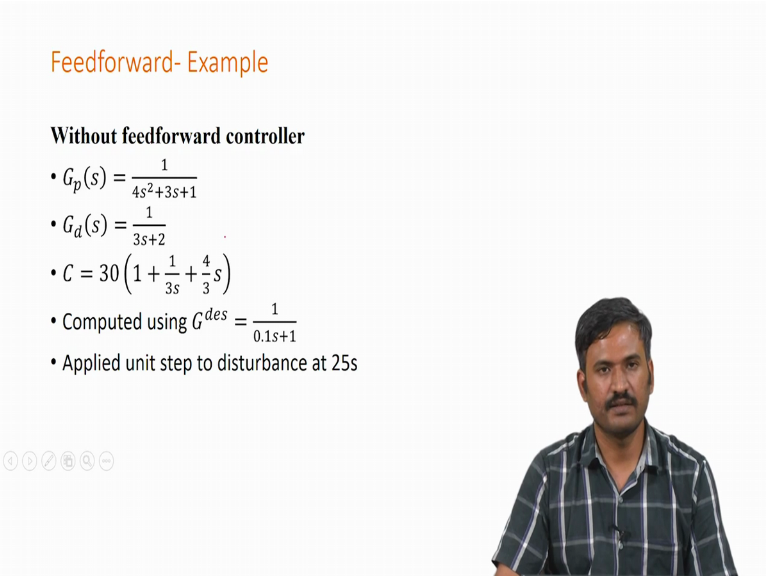

So the same feed forward example given here is configured in the sampling block diagram and we will see the performance difference between the configuration with feed forward control and the configuration without feed forward control. So I have taken a different process transfer function like this and the disturbance transfer function I have taken as 1 by 3 S + 2, based on this process transfer function and the desired configuration I have used direct synthesis to compute this controller configuration and unique step variation has been introduced at 25 seconds in the disturbance. Now with feed forward controller the same system has been used and the same controller which I have tuned for without configuration is used along with additional feed forward controller computed as GD by GP, so that will constitute to - 1 by 3 as + 2 into 4 S square + 3 S + 1.

Now for simplicity I have multiplied and divided by S so that I have a filter - S by 3 S + 2 and 4 S square + 3 S + 1 divided by S as my PID controller. So based on this I have computed P I and D parameters and I have entered these parameters into the PID block, this filter has been added for ease of implementation.

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So let us look at the Matlab simulation, First let us look at the case where there is no feed forward. Now notice that notice that there is an oscillation present in the variable output variable Y here, and here is where the disturbance here is where the disturbance is introduced so this place is where the disturbance is introduced and it takes 10 or 15 seconds to die down. Notice that it dies down after 15 seconds, now here you can see I have given the same step change in the set point to PID controller and the transfer function I have given as given in that slide and the step response so let us just look at the output.

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Now what you are looking at here is two different scenarios where we have output 1, input 1, output 2 and input 2, both of them have oscillations here till 15 seconds in the case where there is no feed forward control. But in the case of feed forward control the oscillations die down faster and it stops around 35 seconds and this is the input profile of both the cases. As you can see the change in the input with respect to the change in the activation of disturbance happens slowly, but in the case of feed forward control the action was passed first then it gradually reduced to steady state.

So we have looked at two advance control techniques which are cascade control and feed forward control, the key idea of both the controls is that we have additional information in terms of either the disturbance measurement or additional variable measurement present like the level of the system. The way with which we tune cascade system is in General tuned from inside out, so the 1st you tune the controller C 2 so that you have desired response from this loop inner loop and then you tune C 1 such that the whole of that closed loop has the desired trajectory or the desired response. So with this I finish this tutorial, we will see decoupler methods and model predictive control tutorial in the next video, thank you.